The pace of change in present day world is posing a challenge to our coping capacity. Since 1950, population has doubled and global economy has nearly quintupled. The demand for energy generation has grown at a phenomenal rate with the food grain requirement and water use nearly tripled. The burning of fossil fuels has increased nearly fourfold as also the concomitant carbon emissions. With the increase of emissions, atmospheric green house concentrations, (carbon dioxide, nitrous oxide, methane, halogenated hydrocarbon, tropospheric ozone) have continued to increase. Although the sensitivity of climate system to green house gas concentrations is not yet well known, the evidence suggests that there is discernible human influence on climate change. According to an assessment, doubling of carbon dioxide concentration in the atmosphere or an equivalent increase of a mixture of green house gases (GHGs) can cause 1.5 to 4.5 °C rise in global temperature with likely impacts such as sea level rise, floods and droughts.

GHG emissions are the products of complex dynamic systems dictated by socio-economic conditions and technological change. The Inter-governmental Panel on Climate Change (IPCC) has developed various scenarios to represent the driving forces and emissions based on available scientific knowledge and underlying uncertainties. The IPCC has been involved in analysis of technologies and measures to reduce the GHG emissions and to enhance the GHG sinks in various sectors including agriculture, energy, forestry, housing, industry, transport and waste management. These options and opportunities deserve serious considerations in our pursuits for sustainable development even without the threat of Climate Change.

This issue of Parivesh is an attempt to provide an overview of the climate change processes and abatement possibilities.

The Information has been compiled and collated by Shri Bharat W., Assistant Environmental Engineer, under the guidance of Shri Lalit Kapur, Senior Environment Engineer and Dr. B. Sengupta, Member Secretary, Central Pollution Control Board.

(Dilip Biswas)
Chairman, CPCB
MESSAGE

8th October, 2002

Change is the essence of evolution. But the change in the recent years has been much faster and unforeseen which calls for concern. Climate Change and Global Warming attributed to emissions of green house gases from human activities is a major threat to our survival and well-being. The United Nations Framework Convention on Climate Change (UNFCCC) mooted at the Earth Summit in 1992 is a landmark agreement of the global community to meet the challenge of the climate change. In 1997, the Kyoto Protocol set the targets and time tables for reduction of emissions to implement the Convention.

Over the years, the countries constituting the Conference of Parties (COP) to the Convention had seven Sessions in different parts of the globe. The issues relating to implementation of the Convention and Kyoto Protocol have been deliberated in these Sessions. However, there are a number of issues concerning mitigation of and adaptation to climate change which remain un-resolved. To take a step forward, the Ministry of Environment and Forests, Government of India will host the 8th Session of the Conference of Parties (COP-8), in which more than 5000 delegates from different countries are expected to participate. Modalities for enforcement of the Kyoto Protocol and key concerns of developing countries will be discussed in the forthcoming COP-8 to be held at New Delhi from 23rd October to 1st November, 2002.

I am happy that the Central Pollution Control Board has chosen “Climate Change” as the theme for the special issue of its Newsletter (Parivesh). I am sure, it will help in dissemination of useful information related to climate change.

(T. R. BAALU)
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1.0 INTRODUCTION

Climate change, also called global warming, refers to the long-term fluctuations in temperature, precipitation, wind and other elements of the Earth’s climate system. The Intergovernmental Panel on Climate Change (IPCC), established jointly by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) in 1988, has been mandated to assess all available factual information on the science, the impacts, and the economies of climate change and on the adaptation/mitigation options to address climate change. Since the Earth Summit in Rio in 1992, it has been a long march for the world to reach a consensus and to commit together, on the road to action in combating global warming. The first international approach to climate change had taken shape with the development of the United Nations Framework Convention on Climate Change (UNFCCC). Adopted in 1992, the UNFCCC set a framework for action aimed at stabilization of greenhouse gas (GHG) concentrations, in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The first Conference of the Parties to the Convention (COP-1) was held in Berlin in March – April, 1995. During the COP-1, it became clear to the world community that ‘Rio is not enough’ and pressed for adequacy of commitment by the developed countries for reduction of GHGs emissions. Accordingly, a Protocol to the Climate Change Convention was adopted in Kyoto in 1997, now known as the Kyoto Protocol. The objective of the Kyoto Protocol is aimed at bringing down the global GHG emissions by 5.2% during the year 2008-2012.

The IPCC estimates that global mean surface temperature would be 2°C above the pre-industrial levels by the year 2030, and about 4°C above pre-industrial levels by the year 2090. Already, findings so far suggest that the earth’s climate has risen by 0.3 to 0.6°C since the late 19th century. Global sea-level has risen by 10-25 cm over the past 100 years. It is expected to rise between 9 cm & 29 cm by 2030 and 26 cm & 96 cm by 2090. Research by the International Rice Research Institute, Manila, has indicated that every 1°C rise in temperature will result in a 10 percent fall in the yield of rice.

Ever since the inception of the UNFCCC in 1992, the Govt. of India has been very active in the climate change negotiations. India is a party to the UNFCC and was the 38th country to ratify it on November 01, 1993. The Ministry of Environment & Forests is the nodal Ministry for all environment related activities in the country and is the nodal Ministry for coordinating the climate change policy as well. The working group on the FCCC was constituted to oversee the implementation of obligations under the FCCC and to act as a consultative mechanism in the government for inputs to policy formulation on climate change. To enlarge the feedback mechanism, the Govt. of India has constituted the Advisory Group on Climate Change under the chairmanship of the Minister of Environment & Forests.
2.0 THE GREENHOUSE GASES

The Earth’s atmosphere primarily consists of oxygen and nitrogen, but neither play any significant role in what is called the greenhouse effect [see Figure 1.0], as both are essentially transparent to terrestrial radiation. The gases currently known to cause the greenhouse effect include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), chlorofluorocarbons (CFCs), and two CFC substitutes, hydrochlorofluorocarbon (HCFC-22), and perfluoromethane (CF₃). Of these carbon dioxide, methane, nitrous oxide and ozone are the naturally occurring greenhouse gases. Certain human activities however add to the levels of most of these naturally occurring gases. Carbon dioxide is responsible for over half the enhancement of the greenhouse effect. The greenhouse effect is primarily a function of the concentration of water vapour, carbon dioxide, and other trace gases in the atmosphere that absorb the terrestrial radiation leaving the surface of the Earth, and act like a blanket over the earth’s surface, keeping it warmer than it would otherwise be. Changes in the atmospheric concentration of these gases can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called the radiative forcing, which is a measure of changes in the energy available to the Earth-atmosphere system. Holding everything constant, increases in greenhouse gas concentrations in the atmosphere will produce positive radiative forcing (i.e. net increase in the absorption of energy by the Earth).

Figure 1.0: The Greenhouse effect
The global carbon cycle consists of the various stocks of carbon in the earth system and the flow of carbon between these stocks. Carbon in the form of inorganic and organic compounds, notably CO₂, is cycled between the atmosphere, oceans, and terrestrial biosphere. The largest natural exchanges occur between the atmosphere and terrestrial biota and between the atmosphere and ocean surface waters. Figure 2.0 illustrates the carbon stocks and its flows associated with the different ecosystems. The carbon stocks associated with the different ecosystems are stored in above ground and below ground biomass, dead organic matter, and soils. Carbon is withdrawn from the atmosphere through photosynthesis, and returned by oxidation process that include plant respiration, decomposition, and combustion. Carbon is also transferred within ecosystems and to other locations. Both natural processes and human activities affect carbon flows. Mitigation activities directed at one ecosystem component generally have additional effects influencing carbon accumulation in, or loss from, other components.

**Figure 2.0:** The global carbon cycle, showing the carbon stocks in reservoirs (in Gt C = 10¹⁵ g C) and carbon flows (in Gt C yr⁻¹) relevant to the anthropogenic perturbation as annual averages over the decade from 1989 to 1998. Net ocean uptake of the anthropogenic perturbation equals the net air-sea input plus runoff minus sedimentation (source: Schimel et al., 1996)
Table 1: Greenhouse gases affected by human activities

<table>
<thead>
<tr>
<th>Time Zone</th>
<th>CO₂</th>
<th>CH₄</th>
<th>N₂O</th>
<th>CFC-11</th>
<th>HCFC-22</th>
<th>CF₆</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-industrial concentration</td>
<td>~280 ppmv⁽ᵃ⁾</td>
<td>~700 ppbv⁽ᵇ⁾</td>
<td>~275 ppbv</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Concentration in 1992</td>
<td>358 ppmv</td>
<td>1720 ppbv</td>
<td>312 ppbv⁽ᵗ⁾</td>
<td>268 pptv⁽ᵗ⁾</td>
<td>110 pptv</td>
<td>72 pptv⁽ᵗ⁾</td>
</tr>
<tr>
<td>Recent rate of concentration</td>
<td>1.5 ppmv/yr</td>
<td>13 ppb/yr</td>
<td>0.6 %/yr</td>
<td>0.75 ppbv/yr</td>
<td>18-20 pptv/yr</td>
<td>7-8 pptv/yr</td>
</tr>
<tr>
<td>(during 1980s)</td>
<td>0.4 %/yr</td>
<td>0.6 %/yr</td>
<td>0.25 %/yr</td>
<td>0.5 %/yr</td>
<td>5 %/yr</td>
<td>2 %/yr</td>
</tr>
<tr>
<td>Atmospheric lifetime (in years)</td>
<td>50-200⁽ʰ⁾</td>
<td>9-15⁽ʰ⁾</td>
<td>120</td>
<td>50</td>
<td>12</td>
<td>50,000</td>
</tr>
</tbody>
</table>

Note: (a) Part per million by volume, (b) Part per billion by volume, (c) Part per trillion by volume
(d) No single lifetime by CO₂ can be defined because of the different rate of uptake by different sink processes.
(e) This has been defined as an adjustment time that takes into account the indirect effect of methane on its own lifetime.
⁽ᵗ⁾ estimate from 1992-1993 data.
[Source: IPCC 1996a]

3.0 CLIMATE CHANGE IMPACTS

The Working Group II Report of the IPCC assessing the Impacts, Adaptation, and Vulnerability concludes, inter alia, that the global average surface temperature has increased by 0.6 ± 0.3 °C over the 20ᵗʰ century, and that, for the range of scenarios developed in the IPCC Special Report on Emission Scenarios (SRES), the global average temperature is projected by models to warm 1.4 to 5.8 °C by 2100 relative to 1980. It also concludes that the globally average sea level is projected by models to rise 0.09 to 0.88 m by 2100. These projections indicate that the warming would vary by region, and be accompanied by increases and decreases in precipitation. In addition there would be changes in the variability of climate, and changes in the frequency and intensity of some climate phenomena. Many human associated systems sensitive to climate change include water resources, agriculture and forestry; coastal zones and marine system; human settlements, energy, and industry; insurance and other financial services; and human health. The vulnerability of these systems varies with geographical location, time, and social, economic, and environmental conditions. Natural system can be specially vulnerable to climate change because of limited adaptive capacity. Some of these systems may undergo significant and irreversible damage. Natural system at risks include glaciers, coral reefs, mangroves, tropical forests, polar and alpine ecosystems etc. While some species may increase in abundance or range, climate change will increase existing risks of extinction of some more vulnerable species and loss of biodiversity.

The vulnerability of human societies and natural systems to climate extremes is demonstrated by the damage, hardship, and death caused by events such as droughts, floods, heat waves, avalanches, and windstorms. While there are uncertainties attached to estimates of such changes, it is however established
that the geographical extent of the damage or loss, and the number of systems affected, will increase with the magnitude and rate of climate change. The effects of climate change are expected to be greatest in the developing countries in terms of loss of life and relative effects on investment and the economy. Many regions that are vulnerable to climate change are also under pressure from forces such as population growth, resource depletion, and poverty.

India could be more at risk than many other countries from changes in temperature and sea level. Models predict an average increase in temperature in India of 2.3 to 4.8 °C for the bench mark doubling of carbon dioxide scenario (Lonergan, World Bank Technical Paper No.402, 1998). Temperatures would rise more in Northern India than in Southern India. In the North Indian Ocean under a doubling, the average number of tropical disturbance days could increase from 17 to 29 a year (Haarsma et al Climate Dynamics, Vol.8, 1993), while, without protection, approximately 7 million people would be displaced, and 5,760 Km² of land and 4,200 Km of road would be lost (Asthana, JNU, New Delhi, 1993). The dominant cost would be the land loss, accounting for 83 percent of all damages. For the same CO₂ doubling scenario, a crop simulation study estimates that wheat yields could decrease between 26 and 68 percent (Rao and Sinha, Impacts of climate change on Stimulated Wheat production in India, 1984). Even allowing for adaptation options, agricultural losses could be significant. The loss in farm revenues is estimated at 9 to 25 percent for a temperature rise of 2 to 3°C (Kumar and Parikh, World Bank Technical Paper No.402, 1998).

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**Figure 3.0:** Exposure, impacts and vulnerabilities and the adaptation loop - a corelation
Figure 3.0, illustrated above indicates the assessment of the Working Group II, of the IPCC, on the climate system. Human activities that change the climate expose natural and human systems to an altered set of stresses or stimuli. Systems that are sensitive to these stimuli are affected or impacted by the changes, which can trigger autonomous, or expected adaptations. These autonomous adaptations will reshape the residual or net impacts of climate change. Policy responses in reaction to impacts already perceived or in anticipation of potential future impacts can take the form of planned adaptations to lessen the adverse effects or enhance beneficial ones. Policy responses can also take the form of actions to mitigate climate change through greenhouse gas emission reductions and enhancement of sinks.

Further, in the Indian context, climate change could represent an additional stress on the ecological and socioeconomic system that are already facing tremendous pressure due to rapid urbanization, industrialization and economic development. Moreover, as our economy is closely linked to our natural resources, India is considerably vulnerable to the impacts of climate change. A study conducted jointly by the Indian Agricultural Research Institute, New Delhi and Central Institute of Dryland Agriculture, Hyderabad, stated that in the current scenario of global climate change, the effect on kharif season is expected to be less than to rabi season. Rainfall in rabi season will, however, have wider uncertainty. Kharif rainfall is likely to increase by as much as 10 percent. Further, the study stated that the onset of monsoon over India is projected to be delayed and often uncertain.

A case study of Orissa and West Bengal (IPCC-1992) estimated that in the absence of protection, a one meter sea level rise would inundate 1700 Km² of predominantly prime agricultural land. The 1999 tropical cyclone that hit Orissa resulted a death toll of about 10,000, clearly demonstrates the extreme significance of impacts related to climate variability. The low lying and densely populated Indian coastline extending to about 6500 Kms remains highly vulnerable to any sea level rise.

On the agricultural front, India, whose 30 percent of the total Gross Domestic Product, is accounted to agriculture and allied activities, climate variability plays a sensitive role. Agricultural productivity is sensitive to broadly two classes of climate induced effects: a) direct effects from changes in temperature, precipitation, or carbon dioxide concentrations, and b) indirect effects through changes in soils, distribution and frequency of infestation by pests, insects, diseases or weeds. Studies predict that rice and wheat yields could decline considerably with climate changes in India.

### 3.1 Climate and Biodiversity

Biodiversity refers to the variety of life on Earth, and its biological diversity. The number of species of plants, animals, micro organisms, the enormous diversity of genes in these species, the different ecosystems on the planet, such as
deserts, rainforests and coral reefs are all a part of a biologically diverse earth. Biodiversity actually boosts ecosystem productivity where each species, no matter how small, all have an important role to play and that it is in this combination that enables the ecosystem to possess the ability to prevent and recover from a variety of disasters. It is feared that human activity is causing massive extinctions. The World Resource Institute reports that there is a link between biodiversity and climate change. Rapid global warming can effect an ecosystems chances to adapt naturally. Unfortunately, in the international policy arena, biodiversity loss and climate change have often moved in wholly unconnected domains.

Over the past 150 years, deforestation has contributed an estimated 30 percent of the atmospheric build-up of CO2. It is also a significant driving force behind the loss of genes, species, and critical ecosystem services. The Kyoto Protocol to the Climate Convention is significant both because of its attempt to reduce the greenhouse gas emissions and because it explicitly acknowledge the role of forests in climate change. The Protocol formally recognized the dual nature of forests – as part of the problem and solution to climate change.

**Climate and biodiversity - the connection:**

- Climate change is affecting species already threatened by multiple threats across the globe – habitat fragmentation due to colonization, logging, agriculture and mining etc. are all contributing to further destruction of terrestrial habitats.
- Individual species may not be able to adapt – species most threatened by climate change have small ranges, low population densities, restricted habitat requirements and patchy distribution.
- Ecosystems will generally shift northward or upward in altitude, but in some cases they will run out of space – as 1°C change in temperature correspond to a 100 Km change in latitude, hence, average shift in habitat conditions by the year 2100 will be on the order of 140 to 560 Kms.
- Pollination may be disrupted – higher temperatures and earlier snowmelt may trigger earlier flowering. This could affect interactions with other species that depend on flowering plants. For example, alteration of the distribution and growing season of the Upland Larkspur could adversely impact pollinators such as broad-tailed hummingbirds and bumblebees.
- Bird species with limited ranges may be lost – For example, the Kirtland Warbler nests in northern Michigan, whose habitat is the declining jack pines in the region.
- Melting of polar ice is causing problems for polar bears
- Coral reef mortality may increase and erosion may be accelerated – in 1998 alone, 16% of the world's coral reef died from higher temperatures. Increase level of carbon dioxide adversely impact the coral building process (calification). Scientists estimate calification could decline 17 to 35 % below pre-industrial levels by 2100.
- Sea level may rise, engulfing low-lying areas – causing disappearance of many islands, and extinctions of endemic island species.
- Whale populations may decline – significant reductions in seal ice could adversely affect the abundance of krill, the primary source of food for whales in the Southern Hemisphere.
- Invasive species may be aided by climate change – exotic species can outcompete native wildlife for space, food, water and other resources, and may also prey on native wildlife.
- Droughts and wildfires may increase – an increased risk of wildfires due to warming and drying out of vegetation is likely.
- Sustained climate change may change the competitive balance among species and might lead to forests dieback.

3.2 Bio-diversity – friendly climate solutions: some facts

a) According to an estimate, it is necessary to reduce emissions by 400 billion tonnes of carbon by 2050 and 1,000 billion tonnes of carbon by 2100, to keep the atmospheric CO₂ levels from exceeding double their historical level. Even at these levels, impacts to biodiversity may be severe. Of the necessary emissions reductions, about 100 billion tonnes of carbon could be achieved through forests and other land based carbon offsets such as restoration of fragmented habitats, reduced impact logging, replacing monoculture farming with agro-forestry, and protection of biodiversity-rich habitat [Source: IPCC 2001; WRI 1999].

b) It is critical that while implementing solutions for climate change we do not unwittingly worsen biodiversity. Hydro-electricity and biomass fuels can be climate friendly, but they may have impacts on biodiversity.

4.0 GLOBAL WARMING POTENTIAL

Global Warming Potential is defined as the cumulative radiative forcing – both direct and indirect effects – over a specified time horizon resulting from the emission of a unit mass of gas related to some reference gas (carbon dioxide - IPCC 1995). A Global Warming Potential (GWP) is intended as a quantified measure of the relative radiative forcing impacts of a particular greenhouse gas. Direct effects occur when the gas itself is a greenhouse gas. Indirect radiative forcing occurs when chemical transformations involving the original gas produce a gas or gases that are greenhouse gases, or when a gas influences the atmospheric lifetimes of other gases. Estimates of greenhouse gases are often presented in units of million of metric tons of carbon equivalents (MMTCE), which weighs each gas by its GWP value, or Global Warming Potential. Carbon comprises 12/44 lbs. of CO₂ by weight. In order to convert emissions reported in teragrams (T₆) of a gas to MMTCE, the following equation is used:
The relation between $G_9$ of a gas and $T_9$ $CO_2$ equivalent can be expressed as follows:

$$T_9 \text{ CO}_2 \text{ Equivalent} = (G_9 \text{ of gas}) \times (GWP) \times \left(\frac{T_9}{1000 \text{ G}_9}\right)$$

Greenhouse gases with long atmospheric lifetimes (e.g. $CO_2$, $CH_4$, $N_2O$, $HFC$, $PFC$ and $SF_6$) tend to be evenly distributed throughout the atmosphere, and consequently global average concentrations can be determined. The short lived gases such as water vapour, atmospheric ozone, ozone precursors (e.g. NOx, CO, and NMVOCs), and tropospheric aerosols (e.g. SO2 products), however, vary regionally, and consequently it is difficult to quantify their global radiative forcing impacts. No GWP are attributed to these gases that are short lived and spatially inhomogenous in the atmosphere.

**Table 2.0: Global Warming Potential and Atmospheric Lifetimes (Years)**

<table>
<thead>
<tr>
<th>Gas</th>
<th>Atmospheric Lifetime</th>
<th>GWP*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>50-200</td>
<td>1</td>
</tr>
<tr>
<td>Methane</td>
<td>12-3</td>
<td>21</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>120</td>
<td>310</td>
</tr>
<tr>
<td>HFC-23</td>
<td>264</td>
<td>11,700</td>
</tr>
<tr>
<td>CF4</td>
<td>50,000</td>
<td>6,500</td>
</tr>
<tr>
<td>SF6</td>
<td>3,200</td>
<td>23,900</td>
</tr>
</tbody>
</table>

Source: IPCC, 1996

*100 year time horizon

The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapour. The indirect effect due to the production of CO2 is not included.

### 5.0 SOURCES OF GREENHOUSE GAS EMISSIONS

Greenhouse gases are emitted by virtually all economic sectors, including residential and commercial energy use, industrial processes, electricity generation, agriculture, and forestry. The *energy sector* is the largest contributor of carbon dioxide emissions in India. The carbon dioxide equivalent emissions (of 1990 reference year emission inventory) from this sector were 565,245 G9, amounting to nearly 55% of the total national emissions of GHGs. These included emissions from road transport, burning of traditional biomass fuels, coal mining and fugitive emissions from oil and natural gas. The second major contribution came from the *agriculture sector*, constituting around 34% of the total emissions, including emissions from enteric fermentation in domestic animals, manure management, rice cultivation, and burning of agriculture residues. Emissions from *industrial processes* came mainly from cement production.
It is widely believed that, despite existing international commitments to curtail growth in greenhouse gas emissions, global carbon emissions from fossil fuel combustion by 2015 may be 61% higher than in 1990. The US Energy Information Administration (EIA) under a reference scenario, estimated that, emissions would grow from 6,012 mmtoe (million metric ton of carbon) in 1990 to 9,704 mmtoe in 2015 [Ref.: International Energy Outlook 1997]. Still faster economic growth might inflate annual emissions to 11,292 mmtoe in 2015, which may be therefore 87% higher than in 1990. The EIA report clearly illustrates the failure of the industrialized nations to meet their initial commitment to limit emissions in 2000 to 1990 levels. Under the reference scenario, emissions from industrialized nations stood at 15% higher than in 1990 level. And by 2015, emissions from industrialized nations might reach 4,074 mmtoe, a 36% increase over 1990 level. According to the EIA, industrialized nations “are not on a path to stabilizing greenhouse gas emissions from energy use”.

Further, even if industrialized nations were to stabilize emissions at 1990 levels or reduce them further by 2015, the EIA expects global carbon emissions to increase substantially. This will result mainly from growth in fossil fuel use outside industrialized nations, from developing countries and the countries of Eastern Europe and the former Soviet Union. The report suggest that increase in carbon emissions in non-industrial regions is dominated by dramatic growth in fossil fuel demand in Asia, especially India and China. Increased coal demand being an important contributor to the region’s carbon emissions. Relative to petroleum and natural gas, combustion of coal emits 1.5 to 2.0 times more carbon per unit of energy released. And coal consumption would increase rapidly. Carbon dioxide emissions from coal combustion in the developing countries of Asia is expect to grow by a whooping 157% from 1990 level by 2015.

Graph1.0: Global Carbon Emission from Fossil Fuels, 1990-2015.
(Source: US Energy Information Administration)
6.0 GHG EMISSION INVENTORY

6.1 Emission Inventories

An emission inventory is an accounting of the amount of air pollutants discharged into the atmosphere. It is generally characterized by the following factors:
- the chemical or physical identity of the pollutants
- the geographical area covered,
- the institutional entities covered,
- the time period over which emissions are estimated, and
- the types of activities that cause the emissions.

Emission inventories are developed for a variety of purposes such as inputs to air quality models, to develop strategies for policy makers, track progress of standards, and by facilities & regulatory agencies to establish compliance records with allowable emission rates.

6.2 Measuring and forecasting greenhouse gas emission and sinks

A national inventory of GHG emission and sinks is a useful tool for both establishing baseline level for GHG emission, and for identifying options for GHG reductions. Forecasting future level of GHG emissions could serve as a benchmark against which future emission reductions could be measured.

The first step to address climate change is to identify all source categories that emit GHGs, and determine their current emission levels. By developing an inventory of GHG emissions, it is possible to identify those source categories that contribute the most to global warming. The inventory can also be helpful for identifying options for GHG mitigation policies.

The concept of baseline (or reference case) for GHG emission; methods for forecasting reference case emissions and policy – induced emission reductions, and the potential for "leakage" of GHG emission (i.e. GHG emission increases in one sector that result from GHG reductions in another sector) etc. should form the basis for evolving any future forecasting procedures.

Two alternatives may be adopted to project the level of GHG emission reduction viz:
- relative to a static baseline (i.e. 1990 level)
- relative to a forecasted level of emissions.

However, forecasting of GHG emissions has a wide range of uncertainty. Given the degree of uncertainty associated with existing methodologies and available data, projections may not serve any useful purpose. The maximum time frame for projecting emissions in most situations is likely to be 15 – 20 years, the
typical time frame for energy use projections. Beyond that, uncertainties in technological changes alone may call into question the accuracy of forecasts.

7.0 INDIA’S GREENHOUSE GAS EMISSIONS

India has experienced a dramatic growth in fossil fuel CO₂ emissions, and the data compiled by various agencies shows an increase of nearly 5.9% since 1950. At present, India is rated as the 6th largest contributor of CO₂ emissions and China the 2nd. However, our per capita CO₂ of 0.93t per annum is well below the world average of 3.87t per annum. Fossil fuel emissions in India continue to result largely from coal burning with India being the largest producer of coal in the world. India is highly vulnerable to climate change as its economy is heavily reliant on climate sensitive sectors like agriculture and forestry. The vast low lying and densely populated coastline is susceptible to rise in sea level.

The energy sector is the largest contributor of carbon dioxide emissions in India. The national inventory of greenhouse gases under ALGAS (Asia-Least Cost Greenhouse Gas Abatement Strategy) project (funded by the Asian Development Bank, Global Environment Facility and United Nations Development Program) indicates that 55% of the total national emissions come from energy sector. These include emissions from road transport, burning of traditional bio-mass fuels, coal mining, and fugitive emissions from oil and natural gas. Agriculture sector constitutes the next major contributor, accounting for nearly 34%. The emissions under this sector include those from enteric fermentation in domestic animals, manure management, rice cultivation, and burning of agriculture residues. Emissions from industrial sector mainly came from cement production. India is the fourth largest producer of cement after China, Japan and the United States. The ALGAS study presents the latest set of projections of greenhouse gas emissions from India.

The Indian Cement Industry with an annual production of 99 million metric tonne (mmt) of cement contributes about 89 mmt of CO₂ emission @ 0.9 mt of CO₂/mt of cement produced. A comparative CO₂ emission levels in some countries are given below:

<table>
<thead>
<tr>
<th>Country</th>
<th>CO₂ emission(mmt)</th>
<th>Cement Production (mmt)</th>
<th>CO₂/mt of Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>37.71</td>
<td>83.47</td>
<td>0.45</td>
</tr>
<tr>
<td>USA</td>
<td>41.07</td>
<td>85</td>
<td>0.47</td>
</tr>
<tr>
<td>China</td>
<td>248.48</td>
<td>573</td>
<td>0.43</td>
</tr>
<tr>
<td>India</td>
<td>89</td>
<td>99</td>
<td>0.90</td>
</tr>
</tbody>
</table>

mt = metric tonne, mmt = million metric tonne
The basic reason for lower CO₂ emission per tonne of cement in Japan and European countries is the prominence of blended cements. CO₂ is predominantly generated during clinker stage and therefore production of higher tonnage of cement (through blended cement) from same quantity of clinker would reduce the CO₂/tonne of cement. The Report of the Working Group on Cement Industry, commissioned by the Planning Commission, suggests a reduction of CO₂ emission level in the next five years (2002-2007) to about 80 mmt out of the projected cement production of 158.56 mmt (i.e CO₂ emission of 0.50/mt of cement) by adopting the following measures:

- Increased production of blended cements and promotion of its use in large quantities.
- Optimising the pyro-processing system and avenues for reduction in electrical power consumption.
- Increased afforestation and sink potential for CO₂.
- Recovery of waste heat for cogeneration of power.
- Optimising particle size distribution of fine coal.
- Use of Alternate fuel(Oil, gas)/Waste derived fuel.
- Increased use of marginal grade limestone.
- Manufacture of reactive belite cement.

It is now expected that going by the present trend, carbon dioxide emissions from energy sector for India may be ten times greater than the 1990 level, by the year 2010. Though relatively small in magnitude, forestry and land use emissions of methane are also expected to grow rapidly. On the other hand, agricultural emissions of methane accounting for 32% of the present global warming potential, are expected to grow slowly.

Table 4.0: India's Greenhouse Gas Inventory for 1990 (G₉)

<table>
<thead>
<tr>
<th>Greenhouse gas sources and Sinks</th>
<th>CO₂ emissions</th>
<th>CO₂ removals</th>
<th>CH₄</th>
<th>N₂O</th>
<th>NOₓ</th>
<th>CO</th>
<th>CO₂ equivalent (CO₂+CH₄+N₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Fuel combustion</td>
<td>508,600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>508,600</td>
</tr>
<tr>
<td>1. Energy and transformation industries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Biomass burning</td>
<td>300,460</td>
<td>1,579</td>
<td>11</td>
<td>400</td>
<td>11,492</td>
<td>36,569</td>
<td></td>
</tr>
<tr>
<td>B. Fugitive emissions from fuels</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Solid fuels</td>
<td></td>
<td>330</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6,930</td>
</tr>
<tr>
<td>2. Oil and natural gas</td>
<td></td>
<td>626</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13,146</td>
</tr>
<tr>
<td>Total emissions from energy sector (fuel combustion + fugitive)</td>
<td>508,600</td>
<td>2,535</td>
<td>11</td>
<td>3,084</td>
<td>14,965</td>
<td>565,245</td>
<td></td>
</tr>
<tr>
<td>II. Industrial processes</td>
<td>24,200</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24,510</td>
</tr>
<tr>
<td>Greenhouse gas sources and Sinks</td>
<td>CO\textsubscript{2} emissions</td>
<td>CO\textsubscript{2} removals</td>
<td>CH\textsubscript{4}</td>
<td>N\textsubscript{2}O</td>
<td>NO\textsubscript{x}</td>
<td>CO</td>
<td>CO\textsubscript{2} equivalent (CO\textsubscript{2}+CH\textsubscript{4}+N\textsubscript{2}O)</td>
</tr>
<tr>
<td>--------------------------------</td>
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</tr>
<tr>
<td>III. solvent and other products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV. Agriculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Enteric fermentation</td>
<td>7,563</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>158,823</td>
</tr>
<tr>
<td>B. Manure management</td>
<td>905</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>190,058</td>
</tr>
<tr>
<td>C. Rice cultivation</td>
<td>4,070\textsuperscript{a}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>85,470</td>
</tr>
<tr>
<td>D. Agricultural soils</td>
<td>240</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>74,400</td>
</tr>
<tr>
<td>E. Prescribed burning of Savannas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F. Field burning of agriculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total emissions from agricultural sources</td>
<td>12,854</td>
<td>243</td>
<td>109</td>
<td>3,038</td>
<td>3,366</td>
<td></td>
<td>341,064</td>
</tr>
<tr>
<td>V. Land use change and forestry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Change in forests and other woody biomass stock</td>
<td>-6,171</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-6,171</td>
</tr>
<tr>
<td>B. Forests and grassland conversion</td>
<td>52,385</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52,385</td>
</tr>
<tr>
<td>C. Abandonment of managed lands</td>
<td>-44,729</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total emissions from land use change and forestry sector</td>
<td>52,385</td>
<td>44729</td>
<td>1,465</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI. Waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Solid waste disposal on land</td>
<td>334</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7,014</td>
</tr>
<tr>
<td>B. Domestic and commercial wastewater</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,029</td>
</tr>
<tr>
<td>C. Industrial wastewater</td>
<td>2,905</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>61,005</td>
</tr>
<tr>
<td>D. Other waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total emissions from waste</td>
<td>3,288</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>69,048</td>
</tr>
<tr>
<td>Total national emissions and removals</td>
<td>585,185</td>
<td>50,900</td>
<td>18,477</td>
<td>255</td>
<td>3,193</td>
<td>18,003</td>
<td>1,001,352</td>
</tr>
</tbody>
</table>

\textsuperscript{a} CO\textsubscript{2} emissions from biomass burning are not included in the national totals.

\textsuperscript{b} CH\textsubscript{4} emissions according to IPCC 1996 methodology.

\textsuperscript{c} CO\textsubscript{2} equivalents are based on global warming potentials (GWP\textsubscript{s}) of 21 for CH\textsubscript{4} and 310 for N\textsubscript{2}O. NO\textsubscript{x} and CO are not included, since GWP\textsubscript{s} have not been developed for these gases. Bunker fuel emissions are not included in the national total.

\textsuperscript{d} NO\textsubscript{x} and CO emissions are computed for the transport sector.

[Source: Asia least-cost Greenhouse gas abatement strategy, Asian Development Bank]
Table 5.0: Global total carbon emissions by region, reference case, [1990-2015]

<table>
<thead>
<tr>
<th>Region/Country</th>
<th>Past</th>
<th>Projection</th>
<th>Average annual percent change, 1995-2015</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrialized</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>1,561</td>
<td>1,663</td>
<td>1,8251</td>
</tr>
<tr>
<td>United States</td>
<td>1,337</td>
<td>1,424</td>
<td>1,543</td>
</tr>
<tr>
<td>Canada</td>
<td>137</td>
<td>143</td>
<td>160</td>
</tr>
<tr>
<td>Mexico</td>
<td>87</td>
<td>97</td>
<td>123</td>
</tr>
<tr>
<td>Western Europe</td>
<td>1,016</td>
<td>1,014</td>
<td>1,081</td>
</tr>
<tr>
<td>Industrialized Asia</td>
<td>408</td>
<td>473</td>
<td>514</td>
</tr>
<tr>
<td>Japan</td>
<td>308</td>
<td>361</td>
<td>401</td>
</tr>
<tr>
<td>Australasia</td>
<td>100</td>
<td>112</td>
<td>114</td>
</tr>
<tr>
<td><strong>Total Industrialized</strong></td>
<td>2,985</td>
<td>3,151</td>
<td>3,421</td>
</tr>
</tbody>
</table>

**EE/FSU (European Union/Former Soviet Union)**

<table>
<thead>
<tr>
<th>Region</th>
<th>Past</th>
<th>Projection</th>
<th>Average annual percent change, 1995-2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Former Soviet Union</td>
<td>1,029</td>
<td>653</td>
<td>733</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>309</td>
<td>240</td>
<td>278</td>
</tr>
<tr>
<td><strong>Total EE/FSU</strong></td>
<td>1,339</td>
<td>893</td>
<td>1,012</td>
</tr>
</tbody>
</table>

**Developing Countries**

<table>
<thead>
<tr>
<th>Region</th>
<th>Past</th>
<th>Projection</th>
<th>Average annual percent change, 1995-2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>625</td>
<td>821</td>
<td>1,031</td>
</tr>
<tr>
<td>India</td>
<td>159</td>
<td>221</td>
<td>276</td>
</tr>
<tr>
<td>Other Asia</td>
<td>307</td>
<td>432</td>
<td>557</td>
</tr>
<tr>
<td>Middle East</td>
<td>203</td>
<td>254</td>
<td>285</td>
</tr>
<tr>
<td>Africa</td>
<td>205</td>
<td>248</td>
<td>267</td>
</tr>
<tr>
<td>Central &amp; South America</td>
<td>189</td>
<td>220</td>
<td>263</td>
</tr>
<tr>
<td><strong>Total Developing Countries</strong></td>
<td>1,687</td>
<td>2,197</td>
<td>2,660</td>
</tr>
<tr>
<td><strong>Total World</strong></td>
<td>5,012</td>
<td>6,241</td>
<td>7,093</td>
</tr>
</tbody>
</table>


8.0 CLIMATE CHANGE NEGOTIATIONS

Global warming issue became a part of the international agenda in 1988. The climate issue came up at the UN General Assembly in December 1988, as part of a discussion on 'the common heritage of mankind' and was initiated by the small island nation Malta. The UN resolution of 1988 thus recognized climate change as a common concern for mankind. The resolution set up a preparatory committee to work towards an international agreement. The concern for global warming particularly by the industrialized countries heated up since then and 'climate politics' matured with a series of international conferences and formal
negotiations that followed. The momentum culminated in the signing of a Framework Convention on Climate Change (FCCC) and opened for signatures at the Rio Earth Summit in June, 1992. The FCCC aims at stabilization of greenhouse gas (GHG) concentrations, in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Subsequently, the parties to the FCCC adopted the Kyoto Protocol in December, 1997. In the eyes of the developing nations the Protocol is fraught with loopholes as economic concerns, rather than ecological or social justice concerns are invariably the driving force. The main area of contention between the developed countries and the developing countries lies in the sectors pertaining to equity and sustainability. However, the operational details of the Kyoto Protocol have now been finalized after intensive deliberations at Marrakech, on November 10, 2001, which was participated by 171 countries. The way for widespread ratification by governments and the Protocol’s entry into force is now made which is acceptable to governments across nations more or less [As of 17 September 2002, 94 countries have so far ratified the Protocol]. The Kyoto Protocol can therefore now enter into force and become legally binding after it has been ratified by at least 55 parties to the convention, including the industrialized countries representing at least 55% of the total 1990 carbon dioxide emissions from this group. However, with the US having backed out there seems little chance for the Protocol to finally become a meaningful reality.

The protocol has been guided by Article 3.0 of the FCCC, and marks the first global attempt to place legally binding limits on greenhouse gas emissions from developed countries. In addition to carbon dioxide, the primary GHG, the protocol focuses on five other greenhouse gases viz. methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆). The Protocol calls for 5.2% reduction from their 1990 level of GHG emissions by the developed countries during the period 2008-2012. It also specifies the amount each country must contribute toward meeting the reduction goal. Nations with the highest CO₂ emissions like the United States, Japan and most European nations are expected to reduce emissions by a range of 6 to 8 per cent. By 2005, all industrialized nations that ratify the accord must also show 'demonstrable progress' toward fulfilling their respective commitments under the Protocol. Unfortunately, with the withdrawal from the negotiations by the United States in March 2001, the Protocol now hangs in a crucial balance of any effective implementation. The reconvened 7th Conference of Parties (COP-7) to the UNFCC, in November 2001, in Marrakesh, Morocco, however brought some hope of possible ratification as major decisions have now been agreed upon, including concessions given to Russia and other nations. Key decisions taken at COP-7 included the following:

- Allowing emissions credits generated under the Clean Development Mechanism, Joint Implementation and Emissions Trading among Annex-1 (developed) countries to be treated equally;
- Creating the removal of units to represent credits generated in Annex-1 countries via sinks;
• Establishing guidelines for banking unused emissions credits;
• Allowing non-Annexe-1 countries to unilaterally undertake a CDM project and market the resulting emissions credits;
• Giving Russia an increase in the ceiling for forest management credits; and
• Requiring Annexe-1 countries to report on efforts to protect bio diversity in the context of sink activities.

Some complex issues of the Kyoto Protocol:

Baseline and its implications - The target of 5.2% reduction beyond 1990 level in the commitment period 2008-2012, were dependent on 1990 emissions. This meant that if a country which had high emissions in 1990 and had reduced them between 1990 and thereafter, then it could actually increase its emission once again, or only stabilize these, and not carry out any reductions.

As an example one can analyse the case of Australia. In 1990, as much as 30 percent of the emissions were from deforestation, which eventually became a blessing for the country – for, instead of penalizing for creating the problem in the first place, Australia has been able to use its emission to its advantage, by winning the right to count any improvement from its 1990 level as its national credit. And as its deforestation rate has been controlled, it actually can increase its emission above and beyond the figure of 8 percent it is expected to reduce. On the other hand, USA and Japan were lobbying hard to change the date of baseline from 1990 to 1995. The reason for this lies in the fact that both the countries have made a significant increase in carbon emissions between 1990 and 1995.

Flexible mechanisms - The Kyoto Protocol includes three mechanisms - Art.6 (Joint Implementation), Art.12 (Clean Development Mechanism) and Art.17 (Emissions Trading), paving an explicit way for developed countries to meet their Kyoto targets easily. The cheapest and the most attractive option for meeting the emission targets of the North (i.e. developed countries-Annexe I) being the Clean Development Mechanism (CDM) that will be operated on the project basis in the South (i.e. under developed countries). This implies that, as global warming is bound to be unsolved even by the end of this century, the South would have to pay a heavy price in future once they have reached a high level of energy efficiency through means like CDM. For by then the cost of carbon cutting will be very high even for the developing countries, which would eventually have to do the carbon cutting on their own. So what form of international cooperation would exist then is not answered by the protocol. The next issue comes on the question of energy-efficient technology, which the North wishes to push to the South through CDM. As technology up-gradation is a continuous process, hence what is the most efficient technology at the time of implementation of the CDM project, may be obsolete within few years that follows.

Principle of equity - Defining the rights and responsibilities of all nations within an equitable framework is not placed in the Kyoto Protocol. So long as the world
remains within a carbon based energy economy, equitable sharing of the 'atmosphere' shall remain a critical issue, especially for poor developing countries who need a maximum space for their future economic growth.

8.1 Development, Equity and Sustainability

There are fundamental scientific and epistemological links between development, equity and sustainability issues and climate change. The concept of sustainable development could only be gauged by its three attributes viz. economic, social and environmental. A consistent integration of development, equity and sustainable development is a necessity to develop an effective and practical climate change strategy. Many national policies taken today could well affect the future climate change prospects significantly. While mainstream economics which is used for practical policy making has often ignored many crucial aspects of environmental and social dimensions of sustainable development, there is a small growing body of economic analysis and application which seeks to address such shortcomings.

Equity in the context of a social decision requires a fair and just outcome. It is an important element of the collective decision-making framework needed to respond to global climate change for a number of reasons, including: a) moral and ethical concerns; b) facilitating effectiveness; c) sustainable development; and d) requirement of the UNFCC. The principles of justice and fair play is a fundamental human right. Most modern international agreements including the UN Charter, enshrine moral and ethical concerns relating to basic equality of all human beings and the existence of inalienable and fundamental human rights. Equitable decisions generally carry greater legitimacy and encourage parties with differing interests to co-operate better in carrying out mutually agreeable decisions. Therefore, a successful implementation of a collective human response to the problem of global climate change will require the sustained collaboration of all sovereign nation states. While penalties and safeguards will play a role, decisions that are widely acceptable as equitable are likely to be implemented with greater willingness and goodwill than those enforced under conditions of mistrust or coercion.

8.2 Ancillary effects of climate change policies

Climate change policies are commonly evaluated on their potential to reduce greenhouse gas emissions. However, they also have potential indirect or ancillary effects on various sectors such as public health, transportation and ecosystem. Therefore, it is important to understand the ancillary effects of policies on climate change in order to have a complete picture of the potential consequences they have for the environment and the economy. The term ancillary benefits of greenhouse gas mitigation policies have been defined as the social welfare improvements from greenhouse gas abatement policies other than those caused by changes in greenhouse gas emissions, which incidentally arise as a consequence of mitigation policies.
Figure 4.0: Ancillary benefits of GHG mitigation

All said however, there is no denying that many uncertainties exists in ancillary effects analysis, and it requires a very careful and transparent approach, including considering of ancillary costs, if major policy mistakes are to be avoided. There are again far more uncertainty when it comes to the developing countries, as practically no data are available for analysis. Most of the ancillary effects till date came from the developed countries, especially USA and Europe. These data are again based on detailed, national assessments of health and other impacts and values. The question of which effects are direct and which are ancillary are again a conflict zone when it comes to the developing countries. In the developed countries with quantitative commitments under the Kyoto Protocol, governments are compelled to consider alternative approaches to meeting the Kyoto targets, their costs and benefits. Hence, there is little fundamental difficulty with the consideration of ancillary effects of climate policies in principle. In this context, it is important that the potential CDM projects initiated are assessed to ensure development needs.

9.0 GHG MITIGATION OPTIONS, SINKS AND BARRIERS

9.1 Mitigation Options

The challenges of climate change mitigation involves diverse issues – economic, political, social and environmental. As the National GHG inventory for India shows, the major increase in GHG emissions over the next 20 years would be related to energy consumption. As India has abundant coal deposits, it is beyond doubt that coal will be the dominant source of energy. Therefore, energy efficiency measures in this sector remains our prime concern. Power generation in India is expected to reach a peak demand of 176 GW by 2012, and the total energy requirement will be 1058 billion units. Therefore, energy efficiency and increasing use of renewable energy or a move towards low carbon options are the two main measures that can greatly reduce GHG emissions. With the rising
demand for energy, power generation specially coal fired power plants, will form a major share of capacity additions. Mitigation option in the power sector include clean coal technologies and renewable energy sources. Options such as bagasse-based co-generation and combined cycle plants generate lesser emissions per kWh of electricity than the conventional power generation system. With a vast rural population and several remote areas, renewable energy could be the means to clean energy.

Similarly, small hydro, wind and biomass-based power, though more expensive than conventional coal-based power plants, provides significant abatement opportunities. Options for energy efficiency in all sectors, shall however be selected on the basis of three main criteria viz.

a) consistency with national development priorities
b) relatively high level of energy conscription in the base activity; and
c) the relatively large GHG reduction potential offered by the abatement technology.

Specific abatement strategies for the energy sector include fiscal incentives and taxes, voluntary emissions reductions, green rating, and capacity building etc. Another area of importance from mitigation aspects in the power sector in the Indian context is the transmission and distribution losses, which is energy loss, and hence, emissions. There is considerable scope of reducing losses, which eventually translates into a large mitigation potential. Electricity demand in India has been increasing at an annual average of 8.8% during the past 35 years. Thermal Power accounts for most of this electricity generation. Its share in the total generation was 82% in 1997 and is expected to increase to 79% by 2015. Therefore, the use of using energy efficient appliances can also contribute a lot in indirect reduction of CO₂ by way of reducing the demand of power consumption. Barriers however still exist that hinder adoption of electricity conservation and demand management in India. Two major categories of barriers are: a) Macro-level barrier – either policy induced or that which exists in the absence of appropriate policies and; b) Micro-level barriers – that related to the individual characteristics of consumers and the economic environment they face.

In the forestry sector, IPCC Second Assesment Report categorises three broad options viz.

- **Conservation management**: This strategy attempts to conserve the existing carbon storage capacity of forests by halting or slowing down forests deforestation and forests degradation.
- **Storage management**: This strategy attempts to increase carbon strategy in woody vegetation and soil in existing degraded forests, as well as to create new carbon sinks in areas where forests do not exists or have been cleared. These may be achieved by promoting natural regeneration, reforestation on
deforested lands, afforestation of non-forest lands and agro-forestry on crop and pastureland.

- **Substitution management**: This strategy attempts involves the replacement of fossil fuels by renewable fuelwood or other biomass products.

In the **agriculture sector**, methane emissions from rice cultivation remains the major contributor of GHG emissions. Other sources being enteric fermentation, manure management, agricultural soils etc. Abatement strategy in this sector in India can be achieved through the following:

- increasing the digestibility of animal feed by supplementing it with molasses.
- replacing open pit method of manure treatment with small scale digestors.
- using improved paddy varieties and draining fields frequently and;
- encouraging cultivation of rice varieties that emit less CH₄ per unit of output.
- improving application efficiency of nitrogenous fertilizers etc.

The **industrial sector**, as the national inventory of GHG shows, major contribution came from energy intensive sectors like iron & steel, fertilizer, cement, aluminium, paper & pulp etc. Therefore, substantial mitigation option in the industrial process besides change of more efficient process methods include switching energy production options. A few options available for energy efficient options in power, industrial and domestic sector is given as follows:

<table>
<thead>
<tr>
<th>Power Sector</th>
<th>Industrial Sector</th>
<th>Domestic Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined cycle plants</td>
<td>Diesel cogeneration</td>
<td>Efficient refrigerators</td>
</tr>
<tr>
<td>Integrated Gasification Combined Cycle (IGCC)</td>
<td>Iron &amp; Steel</td>
<td>Efficient air conditioners</td>
</tr>
<tr>
<td>Inter-cooled steam injected gas turbine (IST/G)</td>
<td>Basic oxygen furnace</td>
<td>Efficient lighting</td>
</tr>
<tr>
<td>Pressurized fluidized bed combustion (PFBC)</td>
<td>Ultra high power electric arc furnace</td>
<td></td>
</tr>
<tr>
<td>Pulverized coal supercritical boilers</td>
<td>Continuous casting</td>
<td></td>
</tr>
<tr>
<td>Industrial cogeneration</td>
<td>Direct reduction process</td>
<td></td>
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<tr>
<td>Amorphous core transformers</td>
<td>Dry quenching route</td>
<td></td>
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<tr>
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<td>Pulp &amp; Paper</td>
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<tr>
<td></td>
<td>Continuous digesters in paper industry</td>
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<tr>
<td></td>
<td>Cement</td>
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<tr>
<td></td>
<td>Dry kilns</td>
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<tr>
<td></td>
<td>Dry pre-heater kilns</td>
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<tr>
<td></td>
<td>Caustic soda</td>
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<tr>
<td></td>
<td>Membrane process</td>
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<tr>
<td></td>
<td>Soda ash dual process &amp; akzo lime process</td>
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<tr>
<td></td>
<td>Waste heat recovery</td>
<td></td>
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<tr>
<td></td>
<td>High efficiency burners (low excess air)</td>
<td></td>
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<tr>
<td></td>
<td>Heat pump</td>
<td></td>
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<tr>
<td></td>
<td>High efficiency motors</td>
<td></td>
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<tr>
<td></td>
<td>Efficient lighting</td>
<td></td>
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</tbody>
</table>

*Source: TERI, New Delhi*
9.2 Sinks as mitigation option

Carbon dioxide is removed from the atmosphere by a number of processes that operate on different time scales, and is subsequently transferred to reservoirs or sinks. Or more simply, we may define ‘Sink’ as ‘any system that removes carbon dioxide from the atmosphere. The fastest process of removal is absorption into vegetation and surface layer of oceans. Sinks are of mainly three types viz. oceanic, terrestrial and inferred or missing. The Kyoto Protocol uses the phrase “land-use-change and forestry” on three occasions: Articles 3.3, 3.4 and 3.7. The Protocol has provisions that allows industrialised countries (Article 3.3) to take into account changes in emissions resulting from human induced land-use, land-use-change and forestry (LULUCF) activities limited to afforestation, reforestation and deforestation since 1990. Simply put in, it allows afforestation as a sink to reduce carbon dioxide levels in the atmosphere. Further, Article 3.4 of the Protocol states that additional human induced activities in the agricultural soils and LULUCF categories may be added to the three mechanisms (Joint implementation, Clean Development mechanism and Emission trading) already counted under the Protocol, subject to certain conditions. Under Article 3.7 the Protocol mentions the phrase land-use change and forestry, in the context of whether this sector was a net source of greenhouse gas emissions in 1990.

In most of the tropical countries, as in India, forestry is dominated by government based institutions. These institutions therefore need support and new insight in order to effectively incorporate mitigation policies and measures in their resource management activities. India has been relentlessly implementing one of the largest reforestation programs in the tropics with over one million hectares planted annually. Nearly half of this reforestation is on degraded forests and village common land. It is estimated that the carbon uptake in forests, degraded forests, and plantations is estimated to offset the gross carbon emissions from the forests sector. Carbon dioxide emissions in India are projected to increase from no-net emissions in 1990 to 77 million tonnes by 2020. This situation can be turned around by promoting agroforestry, which, according to a study by the Indian Institute of Science, Bangalore, can abate 700,000 million tonnes of carbon on a dedicated 69 million hectares of land.

9.3 Barriers to mitigation measures

Greenhouse gas mitigation measures are compounded by several barriers inherent to the process of development. Sustainable development in a participatory framework can minimize these barriers, but the inequitable distribution of income and wealth forms a core feature of barriers to effective implementation of any type of intervention, and those related to climate change are no exception. For any policy decision on GHG reduction any individual country can choose from a large set of possible policies, measures, and instruments to limit domestic GHG emissions. These can be categorized into market based instruments, regulatory instruments, and voluntary agreements of which some may fall into the category of market based instrument. Also for any
country and more particularly for the developing countries, domestic structural
reforms and policies on trade liberalization and liberalization of energy markets
have a great impact on measures that acts as barriers to GHG reduction or
enhance their sequestration by sinks. These policies coupled with
macroeconomics, market oriented reforms, set the framework in which more
specific climate policies would be implemented. During the 1990s several
countries including India and China implemented drastic market oriented reforms
that have had important effects on energy use and energy efficiency, and
therefore on GHG emissions.

Another major barrier in climate change mitigation is the transfer of
environmentally sound technologies from developed to developing countries.
Article 4.5 and other relevant provisions of the UNFCCC defines the nature and
scope of technology transfer, which include environmentally sound and
economically viable technologies and know-how conducive to mitigating and
adapting to climate change. An effective transfer of technology requires fulfilling
three major criteria viz. the technology holder should be willing to transfer the
technology, the technology must fit into the demand of the recipient country and
the transfer must be made at reasonable cost to the recipient. The IPCC Special
Report on technology Transfer (IPCC, 2000) identifies various important barriers
that could impede environmental technology transfer, such as:

- lack of data, information, and knowledge, especially on emerging
technologies;
- inadequate vision about the understanding of local needs and demands;
- high transaction costs and poor macro economic conditions;
- insufficient human and institutional capabilities;
- inappropriate technology adopted and
- poor legal institutions and framework.

10.0 NATIONAL POLICY FOR CLIMATE CHANGE MITIGATION

Climate change is a problem that is inherently different from other environmental
problems with which humanity has grappled. because, the assumption that prior
experience with other air pollution problems is a good model upon which to base
climate policy responses fails at many levels. The consequences of climate
change will be faced primarily by those who are alive in the future. The present
generation has inherited the atmosphere and associated climate from its
ancestors. Options to mitigate climate change include actual emission reductions
and carbon dioxide sequestration. investments in developing technologies that
will make future reductions cheap relative to their current costs. The Govt. of
India has been an active participant in the climate change negotiations since the
inception of UNFCC in 1992. India is a party to the UNFCC and was the 38th
country to ratify it on November 01, 1993. The Ministry of Environment & Forests
is the nodal Ministry for all environment related activities in the country and is the
nodal Ministry for co-ordinating the climate change policy as well. The working
group on the FCCC was constituted to overseas the implementation of
obligations under the FCCC and to act as a consultative mechanism in the Govt. for impacts to policy formulation on climate change. To enlarge the feedback mechanism the Govt. of India has constituted an Advisory group on climate change under the chairmanship of the Minister of Environment & Forests. The policy of the Govt. of India on reduction of GHG emission is based on three broad principles viz.

a) that the primary responsibility of reducing GHG emission is that of developed countries, and hence should show a demonstrable sincerity in initiating actions to address climate change;

b) that the development needs of developing countries are of prime importance; and

c) that the developed world should transfer resources and technologies at favorable terms to the developing world, thereby facilitating developing countries to move towards a sustainable development path.

10.1 Development of National Guidelines & Policy Options for reducing GHG Emissions

The national guidelines or framework for monitoring GHG emissions and policy options for reducing GHG should emphasize not only on issues associated with climate change but also include the following:

- emission forecasting
- setting goals
- policy criteria
- policy evaluation
- organizational and political issues

Climate change and GHG emission and sequestration span many sectors of society and extend far into the future. Furthermore, policy measures to address GHGs overlap with many other public policy objectives, often in a complimentary way. Policy formulations can be a complex undertaking that involves understanding the issues at hand, envisioning the range of actions that governments can take to address those issues, and selecting from within this range the approaches that offer the most potential for achieving multiple public goals. The policy formulation process must respond to local circumstances and must fit within institutional, fiscal, political, and other constraints. The presence of uncertainties, diverse economic sectors, and long lag times between emissions and effects, as well as, the political sensitivity associated with the climate change issue, further complicates actions to reduce GHG emissions. The Govt. of India has nevertheless addressed a large number of local and regional environmental issues in its developmental strategy that are complementary to the climate change issue.
## MAJOR GREENHOUSE GASES

<table>
<thead>
<tr>
<th>Gas</th>
<th>Concentration</th>
<th>Concentration present</th>
<th>Percent Change</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>280 PPM</td>
<td>360 PPM</td>
<td>29 %</td>
<td>Organic matter, forest fires, volcano, fossil fuel, deforestation, change in land use</td>
</tr>
<tr>
<td>Methane</td>
<td>0-70 PPM</td>
<td>1-70 PPM</td>
<td>143 %</td>
<td>Wetlands, organic matter, termites, natural gas and oil wells, waste burning, paddy cultivation, cattle, landfills</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>280 PPB</td>
<td>310 PPB</td>
<td>11 %</td>
<td>Forests, grasslands, oceans, soil, farming, fertilizers, fossil fuels, waste burning</td>
</tr>
<tr>
<td>Chlorofluorocarbon</td>
<td>0</td>
<td>900 PPT</td>
<td></td>
<td>Air conditioners, aerosol sprays, industrial solvents</td>
</tr>
<tr>
<td>Ozone</td>
<td>Not known</td>
<td>Varies with altitude and place</td>
<td>Reduction in stratosphere &amp; increase near surface</td>
<td>Natural occurrence in stratosphere, near earth's surface it evolves with smog</td>
</tr>
</tbody>
</table>

PPM – Parts per million, PPB – Parts per billion, PPT – Parts per trillion
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Published By: Dr. B. Sengupta, Member Secretary, Central Pollution Control Board, Delhi 32

at ENVIS Centre 01

Printing Supervision & Layout: P.K. Mahendru, Mahendra Pandey, Satish Kumar and Mohd. Javed

Fax: 91-11-2217079/2204948 EPABX: 2225792, 2222073, 2222856 TELEX: 031-68440 PCON IN
e-mail: cpcb@alpha.nic.in; Website: http://www.cpcb.nic.in/
Printed at: VINAYAK PRESS